COLUMBIUM (NIOBIUM) AND TANTALUM

By Michael J. Magyar

Domestic survey data and tables were prepared by Robin C. Kaiser, statistical assistant, and the world production table was prepared by Regina R. Coleman, international data coordinator.

Columbium (niobium) is vital as an alloying element in steels and in superalloys for aircraft turbine engines and is in greatest demand in industrialized countries. It is critical to the United States because of its defense-related uses in the aerospace, energy, and transportation industries. Substitutes are available for some columbium applications, but in most cases, they are less desirable.

Tantalum is a refractory metal that is ductile, easily fabricated, highly resistant to corrosion by acids, a good conductor of heat and electricity, and has a high-melting point. It is critical to the United States because of its defense-related applications in aircraft, missiles, and radio communications. Substitution for tantalum is made at either a performance or economic penalty in most applications.

Neither columbium nor tantalum was mined domestically because U.S. resources are of low grade. Some resources are mineralogically complex and most are not currently recoverable. The last significant mining of columbium and tantalum in the United States was during the Korean conflict, when increased military demand resulted in columbium and tantalum ore shortages.

Pyrochlore was the principal columbium mineral mined worldwide. Brazil and Canada, which were the dominant pyrochlore producers, accounted for most of the total estimated columbium mine production in 2004, with Brazil alone accounting for about 88%. The two countries, however, no longer export pyrochlore—only columbium in upgraded valued-added forms produced from pyrochlore. Brazil exported mostly regular-grade ferrocolumbium and columbium oxide, and Canada exported regular-grade ferrocolumbium. The remaining columbium mineral supply came mostly from mining columbite-tantalite in Australia, Nigeria, and certain other African countries. Tantalum mineral was produced mostly from tantalite-columbite mining operations in Australia, which was more than 48% of total estimated tantalum mine production in 2004, and from other tantalum mine operations in Brazil, Canada, Mozambique, and certain African countries. The United States remained dependent on imports of columbium and tantalum materials; Brazil was the major source for columbium, and Australia was the major source for tantalum. The Defense National Stockpile Center (DNSC) offered and sold selected columbium and tantalum materials from the National Defense Stockpile (NDS). Columbium price quotations remained stable, and overall price quotations for tantalite ore increased slightly. Overall reported consumption of columbium in the form of ferrocolumbium and nickel columbium increased. Tantalum consumption was unchanged. Summaries of important columbium and tantalum statistics are listed in tables 1 and 2, respectively.

Legislation and Government Programs

To ensure supplies of columbium and tantalum during an emergency, various materials have been purchased for the NDS (table 3). The NDS had no goals for columbium and tantalum materials as of December 28, 2001. For fiscal year (FY) 2004 (October 1, 2003, through September 30, 2004), the DNSC disposed of columbium metal ingots totaling about 9 metric tons (t) valued at about $304,000. About 103 t of columbium contained in tantalum concentrates (no columbium value was obtained) was sold by the DNSC in FY 2004. The DNSC's columbium carbide inventory was exhausted in FY 2002, and its ferrocolumbium inventory was exhausted in FY 2001. The DNSC also sold about 17 t of tantalum contained in tantalum capacitor-grade metal valued at about $1.69 million, about 18 t of tantalum contained in tantalum metal ingots valued at about $2.06 million, about 9 t of tantalum contained in tantalum oxide valued at about $532,000, and about 161 t of tantalum contained in tantalum minerals valued at about $12.2 million. There were no sales of tantalum carbide powder in FY 2004. As of September 30, tantalum inventory sold but not shipped from the NDS included about 20 t of tantalum contained in tantalum minerals (U.S. Department of Defense, 2004, p. 11-12, 55).

On June 3, the DNSC announced that sales of stockpiled columbium and tantalum materials were suspended following a review of the statutory revenue ceilings for the materials. DNSC sales of 10 commodities, including columbium concentrates and ingots, diamond stone, tantalum carbide powder, concentrates, metal powder, and oxide, and tungsten materials, are subject to a statutory revenue ceiling of $770 million. Sales of these materials ceased once the ceiling was reached (Defense National Stockpile Center, 2004b). On November 15, the DNSC announced that, with the signing of the Ronald Regan National Defense Authorization Act for Fiscal Year 2005, sales resumed with issuance of amendments to the solicitations for the above columbium and tantalum commodities (Defense National Stockpile Center, 2004c).

In its revised Annual Materials Plan (AMP) for FY 2004 and proposed AMP for FY 2005 (October 1, 2004, through September 30, 2005), the DNSC had authority to sell the following columbium and tantalum materials (actual quantity limited to remaining sales authority or inventory, with the exception of columbium concentrates): 254 t of columbium contained in columbium concentrates, 9 t of columbium contained in columbium metal ingots, 227 t of tantalum contained in tantalum minerals, 18 t of tantalum contained in tantalum metal ingots, 18 t of tantalum contained in tantalum metal powder, 9 t of tantalum contained in tantalum oxide, and 2 t of tantalum contained in tantalum carbide powder (Defense National Stockpile Center, 2004a).

Production

Neither columbium nor tantalum was mined domestically in 2004. Domestic production data for ferrocolumbium are developed by the U.S. Geological Survey (USGS) from the annual voluntary domestic survey for ferroalloys. Ferrocolumbium production data for 2004, however, were incomplete at the time this report was prepared.

Cabot Supermetals, Boyertown, PA, (a business unit of Cabot Corporation, Boston, MA) had production capability that ranged from raw material processing through the production of columbium and tantalum end products. H.C. Starck Inc., Newton, MA, was a major supplier of columbium and tantalum products. Reading Alloys Inc., Robesonia, PA, and Wah Chang, Albany, OR, were major producers of high-purity columbium products. Kennametal Inc., Latrobe, PA, was a major supplier of columbium and tantalum carbides (table 9).

In May, KEMET Corporation of Greenville, SC, announced it would move to a lead-free standard termination finish on tantalum manganese dioxide (MnO_2) and organic polymer KO-CAP products. This transition was driven by environmental legislation, such as end-of-life vehicle, restriction on hazardous substances, and waste electrical and electronic equipment directives aimed at eliminating lead from the manufacture of electronic components. The standard termination for all surface-mount tantalum-MnO_2 and organic polymer KO-CAP products will be changed to 100% matte tin from tin-lead. The first ceramic-leaded, conformally-coated axial products with lead-free terminations became available in June 2004. Lead-free ceramic aluminum polymer AO-CAP part types and the KO-CAP T525 series were already available. Lead-free versions of the remaining ceramic through-hole and all tantalum through-hole devices will be developed in 2005. Military T492 and COTS T493 products will not be affected (Metal-Pages, 2004c§[1]).

In August, Cabot Supermetals announced that its new thin films manufacturing facility, located in Etna, OH, was officially open. The new 90,000-square-foot state-of-the-art facility cost Cabot approximately $12 million to build and employs about 20 people. Tantalum-sputtering targets for use in flat-panel displays, magnetics, optics, and semiconductor applications will be produced. Deposition of thin films of tantalum metal on the targets enables the use of copper metal interconnections between transistors in electronic devices. Cabot's new sputtering target manufacturing facility combines automated process control and hands-free robotic material handling, enabling Cabot to produce a high volume of consistent targets on time and at low cost (Cabot Corporation, 2005§).

In September, KEMET announced that it extended its long-term tantalum supply agreement with Cabot Corporation through the end of 2009. As part of the extension, certain terms of the existing contract were also modified to reverse a portion of KEMET's liability related to this contract. As a result, KEMET expected to recognize a noncash special credit in the September-to-December quarter; however, the amount of the special credit had not yet been determined. The terms of this extension enhanced the long-term reliability of KEMET's tantalum supply chain and ensured a long-term supply of tantalum material that allowed KEMET to be cost competitive (KEMET Corporation, 2004b§).

In December, KEMET announced that its first manufacturing facility in Suzhou, China had shipped a total of 10 billion capacitors. The facility received its first business license to operate in March 2003, made its first production shipment in October 2003, and then held a formal grand opening in February 2004. KEMET began shipments of tantalum polymer capacitors from its second Suzhou facility in December. This facility was scheduled to enter high-volume production of polymer-base part types, the fastest growing segment of the tantalum capacitor industry, by March 2005. Consumption of these capacitors was rising sharply in computer-related end-use markets, and Asia was the fastest growing computer manufacturing region in the world (KEMET Corporation, 2004a§).

Consumption

Reported U.S. consumption of columbium in ferrocolumbium and nickel columbium for all end uses increased by about 8% compared with that of 2003. Consumption of columbium by the steelmaking industry was unchanged overall, with consumption up in the carbon and stainless steel end-use categories and down in the high-strength low-alloy end-use category. Demand for columbium in superalloys increased to about 1,250 t from about 933 t (table 4). That portion used in the form of nickel columbium increased to about 540 t from about 473 t. U.S. apparent consumption of all columbium was estimated to be about 5,300 t, a 23% increase compared with that of 2003.

In 2004, estimated U.S. apparent consumption of all tantalum was about 500 t, about the same as in 2003. Tantalum was consumed mostly in the form of alloys, compounds, fabricated forms, ingot, and metal powder. More than 60% of U.S. tantalum consumption was in the electronics industry, mainly in the form of tantalum capacitors. Major end-uses for tantalum capacitors included automotive electronics, pagers, personal computers, and portable telephones.

Columbium.—Columbium and niobium are synonymous names for the chemical element with atomic number 41; columbium was the name given in 1801, and niobium was the name officially designated by the International Union of Pure and Applied Chemistry in 1950. The metal conducts heat and electricity well, has a high melting point (about 2,470° C), is readily fabricated, and is highly resistant to many chemical environments.

Columbium in the form of ferrocolumbium is used worldwide, mostly as an alloying element in steels and in superalloys. Because of its refractory nature, appreciable amounts of columbium in the form of high-purity ferrocolumbium and nickel columbium are used in cobalt-, iron-, and nickel-base superalloys for such applications as heat-resisting and combustion equipment, jet engine components, and rocket subassemblies. Columbium carbide is used in cemented carbides to modify the properties of the cobalt-bonded, tungsten-carbide-base material to impart toughness and shock resistance. It is usually used along with carbides of other metals, such as tantalum and titanium. Columbium oxide is the intermediate product used in the manufacture of columbium carbide, columbium metal, high-purity ferrocolumbium, and nickel columbium. Acceptable substitutes, such as molybdenum, tantalum, titanium,

[1]References that include a section mark (§) are found in the Internet References Cited section.

tungsten, and vanadium, are available for some columbium applications, but substitution may lower performance and/or cost effectiveness.

Columbium was recycled mostly from products of columbium-bearing steels and superalloys; little was recovered from products specifically for their columbium content. Detailed data on the quantities of columbium recycled in 2004 are not available but may compose as much as 20% of U.S. apparent consumption of columbium (Cunningham, 2004a).

Tantalum.—The major use for tantalum as tantalum metal powder is in the production of electronic components, mainly tantalum capacitors. The tantalum capacitor exhibits reliable performance and combines compactness and high efficiency with good shelf life. Applications for tantalum capacitors include communication systems, computers, and instruments and controls for aircraft, missiles, ships, and weapon systems. Because of its high melting point (about 3,000° C), good strength at elevated temperatures, and good corrosion resistance, tantalum is combined with cobalt, iron, and nickel to produce superalloys that are used in aerospace structures and jet engine components. Tantalum carbide, which is used mostly in mixtures with carbides of such metals as columbium, titanium, and tungsten, is used in boring tools, cemented-carbide cutting tools, farm tools, and wear-resistant parts. Owing to tantalum's excellent corrosion-resistant properties, tantalum mill and fabricated products are used for corrosion- and heat-resistant chemical plant equipment, such as condensers, evaporators, heat exchangers, heating elements, and liners for pumps and reactors. Substitutes, such as aluminum, rhenium, titanium, tungsten, and zirconium, can be used in place of tantalum, but are usually used at either a performance or economic penalty.

Tantalum was recycled mostly from new scrap that was generated during the manufacture of tantalum-related electronic components and new and old scrap products of tantalum containing cemented carbides and superalloys. Detailed data on the quantities of tantalum recycled in 2004 are not available but may compose as much as 20% of U.S. apparent consumption of tantalum (Cunningham, 2004b).

Prices

Published prices for pyrochlore concentrates produced in Brazil and Canada were not available because these concentrates were consumed internally by producers of regular-grade ferrocolumbium in Brazil and Canada and are no longer being exported. A price for Brazilian pyrochlore has not been available since 1981, and the published price for pyrochlore produced in Canada was discontinued in early 1989. The columbium price is affected most by the availability of regular-grade ferrocolumbium produced from pyrochlore. The yearend 2004 American Metal Market published price for regular-grade ferrocolumbium was at a range of $6.45 to $6.70 per pound of contained columbium, identical to the range of $6.45 to $6.70 per pound of contained columbium at yearend 2003 and unchanged since July 2003 (American Metal Market, 2004). The American Metal Market published price for high-purity (vacuum-grade) ferrocolumbium was discontinued in February-March 2002 at a range of $17.50 to $18 per pound of contained columbium. The Metal Bulletin price for columbite ore, based on a minimum 65% contained columbium oxide (Nb_2O_5) and tantalum oxide (Ta_2O_5), was discontinued in October 2001 at a range of $5.50 to $7 per pound. According to one industry analyst, "Prices for columbium oxide, other columbium chemicals, columbium metal and various alloys derived from either pyrochlore or other columbium-bearing sources are highly variable and depend on product specifications, volume, and processing considerations" (Mosheim, 2003a).

Significant events affecting columbium prices since 1958 include the following: 1960-70, development of pyrochlore deposits in Brazil and Canada; 1970-79, increased demand and consequent rising prices; 1980, columbium oxide produced from pyrochlore-based feed material; 1981, exports of Brazilian pyrochlore ceased; 1994, production of ferrocolumbium began in Canada; 1997-98, sales of ferrocolumbium from the NDS; and 1998, expansion of ferrocolumbium production capacity in Brazil (Cunningham, 1999a).

The price for tantalum products is affected most by events in the supply of and demand for tantalum minerals. Yearend 2004 published prices for tantalite ore were as follows: Platts Metals Week, a range of $35 to $40 per pound of contained Ta_2O_5, unchanged since November 2004 compared with a range of $30 to $40 per pound of contained Ta_2O_5 at yearend 2003 (Platts Metals Week, 2004); Metal Bulletin Weekly, a range of $34 to $38 per pound of contained Ta_2O_5 since December 8, 2004 (Metal Bulletin Weekly, 2005); and Ryan's Notes, a range of $20 to $25 per pound of contained Ta_2O_5, unchanged since August 2002. The Metal Bulletin published price for Greenbushes, Australia, tantalite ore was $40 per pound of contained Ta_2O_5, 40% basis, unchanged since March 2002 (Metal Bulletin Weekly, 2005). According to one industry analyst, "The pricing of tantalum chemicals, metal powders, alloys, and fabricated articles is generally established by negotiation between buyer and seller. Specifications for a particular chemical, metal powder, or fabricated article of metal or tantalum alloy are dictated by the application, and their influence on processing requirements, and the volume of a specific product, all influence the prices negotiated between buyer and seller" (Mosheim, 2003b).

Significant events affecting tantalum prices since 1958 include the following: 1979-80, tantalum price accelerates to record levels, owing in part to overoptimistic forecasts of market growth; 1982, industry's accumulation of large tantalum material inventories; 1988, drawdown of tantalum material inventories by processors; 1990, purchase of tantalum materials for the NDS; 1991, long-term tantalum supply contracts between major producer and processors; 1998, sales of tantalum minerals from the NDS; and 2000, overoptimistic forecasts of market growth and an apparent shortage of tantalum source materials for processing (Cunningham, 1999b). Based on the AMP for FY 2005, the NDS inventory of tantalum metal powder and ingots could be exhausted in 2005, while the inventory of tantalum carbide powder, minerals, and oxide could be exhausted in 2 to 3 years. However, large inventories of tantalum materials at major processors and adequate production capacity at producers should minimize any impact on tantalum prices.

Foreign Trade

Table 5 lists columbium and tantalum export and import data. For exports, overall trade value and total gross weight increased compared with those of 2003. In descending order, Israel, the United Kingdom, Germany, Japan, Taiwan, and Thailand were the major recipients of the columbium and tantalum materials, on the basis of value, with more than 80% of the total. For imports, overall trade value and total gross weight increased. In descending order, Brazil, Australia, Germany, Estonia, Japan, and China were the major sources of columbium and tantalum imports, on the basis of value, with about 90% of the total.

Imports for consumption of columbium ores and concentrates decreased (table 6). Imports at an average grade of approximately 32% Ta_2O_5 and 30% Nb_2O_5 were estimated to contain about 1.6 t of tantalum and about 1.5 t of columbium. Ferrocolumbium imports rose by about 27%, with Brazil accounting for about 88% of the total. Brazil accounted for about 68% of total value of columbium imports.

Imports for consumption of tantalum ores and concentrates were down slightly compared with those of 2003 (table 7); imports from Australia accounted for about 79% of quantity and about 90% of value. Imports at an average grade of approximately 37% Ta_2O_5 and 16% Nb_2O_5 were estimated to contain about 548 t of tantalum and about 237 t of columbium.

The schedule of tariffs applied during 2003 to U.S. imports of selected columbium and tantalum materials is found in the Harmonized Tariff Schedule of the United States (U.S. International Trade Commission, 2002). Brazil, which was the major source for U.S. columbium imports, accounted for about 84% of the total, in units of contained columbium, and Australia, which was the major source for U.S. tantalum imports, accounted for about 46% of the total, in units of contained tantalum (figures 1, 2).

Net import reliance as a percentage of apparent consumption is used to measure the adequacy of current domestic columbium and tantalum production to meet U.S. demand. For columbium in 2004, net import reliance as a percentage of apparent consumption was 100%. For tantalum, net import reliance as a percentage of apparent consumption was estimated to be about 80%.

World Industry Structure

Principal world columbium and tantalum raw material and product producers are listed in tables 8 and 9, respectively. Annual world production of columbium and tantalum mineral concentrates, by country, is listed in table 10. Brazil and Canada were the major producers of columbium mineral concentrates, and Australia, Brazil, Canada, and Mozambique were the major producers of tantalum mineral concentrates. Tantalum was also available from tantalum-bearing tin slags, which are byproducts from tin smelting, principally from Asia, Australia, and Brazil. However, their importance has decreased with the exception of accumulated inventory owing to the downsizing of the tin industry in the 1980s.

World Review

Australia.—For its financial year ending June 30, 2004, Sons of Gwalia Ltd., West Perth, Western Australia, the leading tantalum producer in the world, reported that tantalum production (Ta_2O_5 contained in mineral concentrates) totaled about 1,043 t and sales totaled about 953 t at its Greenbushes and Wodgina Mines. Production at Greenbushes, approximately 300 kilometers (km) south of Perth and 80 km southeast of the port of Bunbury totaled about 408 t, meeting its fiscal year plan, compared with about 476 t in 2003. Production at Wodgina, approximately 100 km south of Port Hedland in the Pilbara region of Western Australia, totaled about 635 t compared with about 517 t in 2003 and exceeded that of Greenbushes for the second time in its history. Production capacity at Greenbushes and Wodgina totaled about 1,360 t. As of June 30, 2003, Sons of Gwalia reported that Greenbushes tantalum mineral resource base was about 56,100 t of contained Ta_2O_5, including about 26,000 t of contained Ta_2O_5 classified as being tantalum ore reserves, and that Wodgina's tantalum mineral resource base was about 40,300 t of contained Ta_2O_5, including about 23,200 t of contained Ta_2O_5 classified as being tantalum ore reserves (Sons of Gwalia Ltd., 2004, p. 1-2, 5, 9-10, 12).

In November, the administrators of Sons of Gwalia approved an investment program totaling A$18 million (US$13.9 million), the largest approved investment in the tantalum supply chain during the previous 2 years. The West Perth firm, which went into administration 2 months earlier, also confirmed a new long-term, take-or-pay tantalum supply contract with German processor H.C. Starck Inc. The new contract provides for supply of tantalum concentrates from the Greenbushes Mine for the calendar years 2006 through 2008 and will ensure continuity of supply for H.C. Starck following the expiration of the existing contracts in December 2005. The minimum commitment was for about 360 metric tons per year (t/yr) (800,000 pounds per year), with H.C. Starck having the option on a further 90 t (200,000 pounds). Sons of Gwalia also restarted underground mining at Greenbushes, expected to produce about 225 t/yr (500,000 pounds per year) of Ta_2O_5, the world's largest underground tantalum mine. Ramp up to full production was expected to take 18 months (Metal Pages, 2004d§).

Tantalum Australia NL, Balcatta, Western Australia, announced in May that it had signed the first in what it hoped would be a series of contracts with an unnamed African mining company to process about 150 t (330,000 pounds) of tantalite during a 24-month period. The first shipment of tantalite was sent to Tantalum Australia's mineral dressing plant in Balcatta in June, where it was upgraded from a concentrate containing 10% Ta_2O_5 to one containing 20% to 50% Ta_2O_5. The material was to be sold to intermediate producers of tantalum powder, metal, and wire in China, Germany, Thailand, and the United States. Tantalum Australia owned about 2,270 t (5 million pounds) of tantalite resources in Australia and had the capacity to produce about 45 t/yr (100,000 pounds per year) of low-grade tantalite concentrate (Metal Bulletin Daily, 2004).

In September, Australian tantalum producer Gippsland Limited took delivery of the bankable feasibility study on its 40-million-metric-ton (Mt) Abu Dabbab tantalum-tin-feldspar project in Egypt. The study, undertaken by international engineering group Lycopodium, determined that the project could produce in excess of 185 t/yr (412,000 pounds per year) of Ta_2O_5 along with about 980 t/yr of tin metal during the first 20 years of production, based on the design throughput of 1.26 million metric tons per year. The Nedlands, Western Australia, firm agreed to sell about 190 t/yr (420,000 pounds per year) of Ta_2O_5 for a 4-year period to two major tantalum consumers. In May, the company announced that the initial production rate at Abu Dabbab could be as much as 26% higher than planned, based on projected tin revenues, and that the ultimate capacity could double (Metal Pages, 2004g§).

Brazil.—In September, British miner Angus & Ross Plc. agreed to sell Cabot Corporation an option to buy part of the York, United Kingdom-based firm's future Brazilian tantalum concentrate production from 2006 through to 2010 for $275,000. The focus of Angus & Ross's current exploration effort was the Santa Cecilia tantalum-gold prospect in Mato Grosso State in Western Brazil. The company continued to systematically sample the property in an attempt to confirm and extend the known resources and also to discover the hard-rock source of the tantalum-gold deposit underlying the property (Metal Pages, 2004a§).

In March, Gruppo Paranapanema, Brazil's leading tin producer, abandoned plans to build new columbium and tantalum plants and decided to focus instead on raising tin output. The firm's subsidiary, Mamoré Mineração e Metalurgia, had planned to build concentrate and oxide plants at its Pitinga Mine in Amazonia State to process concentrate into about 400 t/yr of Ta_2O_5 and 4,000 t/yr of Nb_2O_5 for the export market. Owing to lower than expected international prices for the metals over a sustained period, the firm decided against proceeding with plant construction. The previously scheduled $50 million expenditure at Pitinga over a 2 year period was cut to $32 million, all of which will go toward increasing tin production (Metal Pages, 2004e§).

Canada.—Production of columbium at the Niobec Mine in St. Honore, 15 km northwest of Chicoutimi, Quebec, was about 3,450 t compared with about 3,270 t in 2003. Sequoia Minerals Inc. shareholders approved a merger with Cambior Inc. at a special meeting allowing Niobec to become a 50-50 joint venture between international gold producer Cambior (product marketing) and Sequoia (mine operator). As a result of the merger, Sequoia became a wholly owned subsidiary of Cambior, and Cambior acquired 50% interest in the Niobec Mine and assumed operation of the mine. Cambior intended to implement its innovation and continuous improvement program during the second half of the year to gradually increase the asset's value over time. The Niobec Mine, in operation since 1976, has a milling capacity of 3,500 metric tons per day. Pyrochlore concentrate produced at Niobec was converted into ferrocolumbium using an aluminothermic process, making the Niobec Mine the third ranked ferrocolumbium producer worldwide. Proven and probable mineral reserves of the mine were estimated to be 22.6 Mt at an average grade of 0.65% Nb205 and were expected to provide at least 15 years of mine life at the current mining rate (Metal Pages, 2004f§).

South Africa.—U.S.-based Pinnacle Resources, Inc. announced that its subsidiary Titan Processors (Pty.) Ltd. Completed the expansion of the acid-leach section of its tantalum refinery in Johannesburg, to enable the South African producer to separate 30 metric tons per month (t/mo) of finished tantalum products. Expansion of the other separation circuits was underway to match the beneficiation plant's capacity. Ore supplies to satisfy this production rate will come from independent miners in Mozambique and Zimbabwe, under contract with Titan to produce the required plant feed. Titan was expected to increase production of high-purity Ta_2O_5 to the designed 30 t/mo production rate from the present 2 t/mo output over a 9-month period without disrupting current operations. The Titan refinery was the only plant in Africa able to beneficiate complex African ores and produce finished tantalum products for export to European or North American refineries (Metal Pages, 2004h§).

Outlook

Columbium.—The principal use for columbium will continue to be as an additive in steelmaking, mostly in the manufacture of microalloyed steels. The production of high-strength low-alloy steel is the leading use for columbium, and the trend for columbium demand, domestically and globally, will continue to follow closely that of steel production as the steel industry is estimated to account for as much as 90% of columbium consumption. (Additional information about the future of the steel industry can be found in USGS Minerals Yearbook, volume I, Metals and Minerals chapter on iron and steel.) Worldwide columbium consumption reached a record level in 2003 and grew further in 2004, in line with increased steel production and further expansion was expected in 2005 and 2006. Demand for columbium, however, does not mirror trends in overall steel production as only 10% of the total steel produced contains columbium. In addition, the geographical distribution of consumption is very uneven. In China, where the growth in steel output has been greatest, the incidence of columbium use was reportedly much lower than in Western countries. This would agree with observations of consumption per unit of steel of other ferroalloys. As a result, there is significant potential for increased demand for columbium in steel, both from growth in total steel output and also from changes in columbium composition (Roskill Information Services Ltd., 2005).

The leading nonsteel use of columbium is in superalloys for, among other applications, aircraft engines. Those markets experienced a sharp fall after the terrorist attacks in September 2001 resulted in an economic downturn and the outbreak of severe acute respiratory syndrome (SARS) caused travel to decline. The commercial aircraft market has since begun to recover and is expanding strongly. For instance, The Boeing Company expected the airline fleet to more than double during the next 20 years with the addition of more than 26,000 new aircraft (Boeing Commercial Airplanes, 2005, p. 4). Nickel-base superalloys (such as alloy 718, which contains about 5% columbium) can account for about 40% to 50% of aircraft engine weight, and they are expected to be the materials of choice for the future owing to their high-temperature operating capability (Cunningham, 2004a, p. I7).

An emerging market for columbium was displacing tantalum in capacitors, owing to columbium's relatively low cost and abundant supply, but development of columbium capacitors has been slowed by technical difficulties. While there has been development of columbium capacitors that can be used in some applications, tantalum content per capacitor has decreased, limiting the potential for market penetration by columbium.

Tantalum.—The main uses for tantalum are in alloys, capacitors, carbides, medical applications, and in the chemical industry with capacitors accounting for over 50% of consumption. Capacitors are used in digital cameras, laptops, mobile phones, video phones, and other electronic devices and the world market reached 19.4 million units in 2003. The Tantalum-Niobium International Study

Center expected tantalum consumption to grow by about 7% per year, mainly owing to the increase in demand for capacitors. In the capacitor segment, smaller case sizes reduced tantalum consumption per unit and tantalum lost market share to other materials, such as aluminum, ceramics, and columbium (Metal Pages, 2004b§).

New sources of tantalum may eliminate the sharp price fluctuations of recent years (Roskill Information Services Ltd., 2005). While Australia supplied about 50% of tantalum production in 2004, other significant production came from Africa, Brazil, Canada, and China, so supply was expected to be sufficient. Future supply prospects are based on reserves in Egypt, Greenland, and Saudi Arabia and there are numerous deposits of tantalum that could be brought into production given the right market conditions. Some large projects, such as Abu Dabbab in Egypt, were already in advanced stages of development; however, future development may be keyed to depletion of Australian resources.

An important component of world tantalum supply is the U.S. Government sales of tantalum materials from the NDS. As of May 31, 2004, tantalum materials authorized for disposal from the NDS totaled about 571 t of contained tantalum, including about 517 t contained in tantalum minerals. Based on the AMP for FY 2005, the NDS inventory of tantalum metal powder and ingots could be exhausted in 2005, while the inventory of tantalum carbide powder, minerals, and oxide could be exhausted in 2 to 3 years.

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TABLE 1

SALIENT COLUMBIUM STATISTICS[1]

		2000	2001	2002	2003	2004
United States:						
Government stockpile releases, Nb content[2]	metric tons	217	-4	9	223	115
Production of ferrocolumbium, Nb content	do.	NA	NA	NA	NA	NA
Exports, columbium metal, compounds, alloys, gross weight	do.	NA	NA	NA	NA	NA
Imports for consumption:						
Mineral concentrates, Nb content[e]	do.	300	290	290	180	165
Columbium metal and columbium-bearing alloys, Nb content[e]	do.	607	1,050	673	743	940
Columbium oxide, Nb content[e]	do.	1,190	1,360	660	590	630
Ferrocolumbium, Nb content[e]	do.	4,400	4,480	4,030	4,080	5,170
Tin slag, Nb content	do.	NA	NA	NA	NA	NA
Consumption, Nb content:						
Raw materials	do.	NA	NA	NA	NA	NA
Ferrocolumbium and nickel columbium[e]	do.	4,090	4,230	3,150	3,650	3,940
Apparent	do.	4,300	4,400	4,100	4,300	5,300
Prices:						
Columbite[3, 4]	dollars per pound	6.25	NA	NA	NA	NA
Ferrocolumbium[5]	do.	6.88	6.88	6.60	6.58	6.56
Pyrochlore[6]	do.	NA	NA	NA	NA	NA
World, production of columbium-tantalum concentrates, Nb content	metric tons	24,800	31,100	32,700 [r]	32,800	34,000 [e]

[e]Estimated. [r]Revised. NA Not available.

[1]Data are rounded to no more than three significant digits, except prices.

[2]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.

[3]Yearend average value, contained pentoxides for material having a columbium pentoxide (Nb_2O_5) to tantalum pentoxide ratio of 10 to 1.

[4]The published price for columbite ore was discontinued in October 2001 at a range of $5.50 to $7.00 per pound of Nb_2O_5 content.

[5]Yearend average value of contained Nb, standard (steelmaking) grade.

[6]Yearend average value of contained pentoxide.

TABLE 2

SALIENT TANTALUM STATISTICS

		2000	2001	2002	2003	2004
United States:						
Government stockpile releases, Ta content[1]	metric tons	242	-53	16	335	225
Exports, gross weight:						
Tantalum ores and concentrates[2]	do.	263	530	232	295	717
Tantalum metal, compounds, alloys	do.	460	486	265	187	503
Tantalum and tantalum alloy powder	do.	108	156	188	280	257
Imports for consumption, Ta content:						
Mineral concentrates	do.	650	690	710	490	450
Tantalum metal and tantalum-bearing alloys[3]	do.	251	316	266	249	590
Tin slag	do.	NA	NA	NA	NA	NA
Consumption, Ta content:						
Raw materials	do.	NA	NA	NA	NA	NA
Apparent	do.	650	550	500	500	500
Prices, tantalite[4]	dollars per pound	220	37	31	28	32
World, production of columbium-tantalum concentrates, Ta content	metric tons	1,070	1,180	1,470 r	1,280 r	1,510

[r]Revised. NA Not available.

[1]Net quantity (uncommited inventory). Negative numbers indicate an increase in inventory.

[2]Includes reexports.

[3]Exclusive of waste and scrap.

[4]Yearend average value of contained pentoxides.

TABLE 3

COLUMBIUM AND TANTALUM MATERIALS IN NATIONAL DEFENSE STOCKPILE INVENTORIES AS OF DECEMBER 31, 2004[1]

(Metric tons of Nb or Ta content)

			Uncommitted			
Material	Stockpile goal[2]	Disposal authority	Stockpile-grade	Non-stockpile-grade	Total	Committed
Columbium:						
Concentrates[e]	--	400	400	21	400	119
Carbide powder	--	--	--	--	--	--
Ferrocolumbium	--	--	--	--	--	--
Metal ingots[e]	--	40	37	--	37	--
Total	--	440	437	21	437	119
Tantalum:[e]						
Minerals	--	580	540	36	580	184
Carbide powder	--	6	6	--	6	--
Metal:						
Capacitor grade	--	17	17	--	17	16
Ingots	--	9	9	--	9	17
Oxide	--	19	19	--	19	--
Total	--	631	591	36	631	217

[e]Estimated. -- Zero.

[1]Data may not add to totals shown because of independent rounding.

[2]Goal effective as of December 28, 2001.

Source: Defense National Stockpile Center.

TABLE 4

REPORTED CONSUMPTION, BY END USE, AND INDUSTRY STOCKS OF FERROCOLUMBIUM AND NICKEL COLUMBIUM IN THE UNITED STATES[1]

(Metric tons of Nb content)

End use	2003	2004
Steel:		
Carbon	820	1,110
Stainless and heat-resisting	612	639
Full alloy	(2)	(2)
High-strength low alloy	1,280	950
Electric	(2)	(2)
Tool	(2)	(2)
Unspecified	--	--
Total	2,710	2,700
Superalloys	933	1,250
Alloys (excluding alloy steels and superalloys)	(3)	(3)
Miscellaneous and unspecified	8	(4)
Grand total	3,650	3,940
Stocks, December 31:		
Consumer	NA	NA
Producer[5]	NA	NA
Total	NA	NA

NA Not available. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Included with "Steel, High-strength low alloy."

[3]Included with "Miscellaneous and unspecified."

[4]Less than ½ unit.

[5]Ferrocolumbium only.

TABLE 5

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS[1]

Class	2003 Gross weight (metric tons)	2003 Value (thousands)	2004 Gross weight (metric tons)	2004 Value (thousands)	Principal destinations and sources, 2004 (gross weight in metric tons and values in thousand dollars)
Exports:[2]					
Columbium:					
Ores and concentrates	170	$1,270	16	$108	Italy 6, $70; China 9, $17; Japan[3], $11; United Kingdom 1, $6; Germany[3], $3.
Ferrocolumbium	143	1,430	294	2,920	Canada 143, $1,600; Mexico 146, $1,270; Chile 4, $38; Trinidad 1, $10; Colombia[3], $3.
Tantalum:					
Synthetic concentrates	70	174	6	61	Republic of Korea 3, $26; Mexico[3], $12; Taiwan 1, $11; Chile 2, $6; Malaysia[3], $3.
Ores and concentrates	295	4,190	717	19,300	China 230, $7,800; Belgium 70, $5,360; France 147, $3,680; Brazil 197, $1,360; Thailand 73, $1,080.
Unwrought, powders[3]	280	154,000	257	152,000	Israel 107, $74,300; United Kingdom 70, $55,400; Japan 29, $6,370; Germany 13, $5,290; Sweden 25, $2,740; El Salvador 5, $2,640; Thailand 1, $1,920.
Unwrought, alloys and metal[3]	22	6,170	20	2,890	Germany 7, $819; Japan 4, $670; France 1, $401; Sweden 4, $337; Canada[3], $275; Mexico 1, $110.
Waste and scrap[3]	46	2,830	321	18,600	United Kingdom 67, $5,800; Germany 111, $4,310; Japan 28, $3,170; Belgium 27, $1,050; China 16, $1,030.
Wrought	119	62,200	162	83,400	Taiwan 6, $16,200; Germany 42, $15,400; Japan 38, $13,700; Israel 19, $13,600; Thailand 20, $5,260; Singapore 2, $2,050; China[3], $478.
Total	XX	232,000	XX	279,000	Israel, $87,000; United Kingdom, $61,200; Germany, $25,800; Japan, $23,900; Taiwan, $16,200; Thailand, $8,260; Sweden, $3,080.
Imports for consumption:					
Columbium:					
Ores and concentrates	23	609	5	41	China 1, $30; Australia 4, $6; Canada[3], $4.
Oxide	837	12,200	906	13,900	Brazil 469, $5,290; Germany 100, $4,140; China 164, $2,150; Estonia 79, $1,000; Russia 93, $647.
Ferrocolumbium	6,280	54,700	7,950	69,000	Brazil 6,990, $59,800; Canada 473, $8,590.
Unwrought, alloys, metal, powder[3]	743	16,400	940	18,500	Brazil 782, $13,900; Estonia 68, $2,220; Germany 58, $1,570; Belgium 14, $231; Kazakhstan 3, $204; China 9, $177.
Tantalum:					
Synthetic concentrates	(4)	10	--	--	All from China.
Ores and concentrates	1,580	60,100	1,480	57,900	Australia 1,750, $52,100; Canada 277, $4,570; Ethiopia 30, $1,240; Japan[3], $30; United Kingdom 1, $27; China[3], $4.
Unwrought, powders[3]	171	38,400	386	98,400	Thailand 140, $31,700; Germany 117, $26,000; Japan 34, $24,100; China 65, $12,300; Ukraine 18, $2,310; Israel 1, $752; Kazakhstan 1, $193.
Unwrought, alloys and metal[3]	46	6,480	166	19,200	Estonia 28, $37,800; Germany 12, $15,300; Austria 2, $10,600; Kazakhstan 61, $8,600; China 17, $2,230; Portugal 29, $1,100.
Waste and scrap[3]	224	12,800	503	20,500	Israel 99, $3,720; Japan 192, $3,580; China 46, $3,390; Austria 30, $2,980; Portugal 13, $1,610.
Wrought	32	7,760	38	10,000	China 21, $8,170; Japan 6, $837; Kazakhstan 2, $444; Austria 1, $264; United Kingdom[3], $211; Canada[3], $106.
Total	XX	209,000	XX	307,000	Brazil, $99,000; Australia, $52,100; Germany, $47,000; Estonia, $42,300; Japan, $28,500; China, $28,400; Austria, $13,600; Kazakhstan, $9,440; Israel, $4,470; Portugal, $2,710.

See footnotes at end of table.

TABLE 5—Continued

U.S. FOREIGN TRADE IN COLUMBIUM AND TANTALUM METAL AND ALLOYS, BY CLASS[1]

XX Not applicable. -- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]For columbium, data on exports of metal and alloys in unwrought and wrought form, including waste and scrap, are not available; included in nonspecific tariff classification.

[3]Correction posted February 2, 2006.

[4]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 6
U.S. IMPORTS FOR CONSUMPTION OF COLUMBIUM ORES AND CONCENTRATES, BY COUNTRY[1]

	2003		2004	
Country	Quantity, gross weight (metric tons)	Value (thousands)	Quantity, gross weight (metric tons)	Value (thousands)
Australia	--	--	4	$6
Canada	--	--	(2)	4
China	9	$210	1	30
Kazakhstan	14	399	--	--
Total	23	610	5	41

-- Zero.

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 7
U.S IMPORTS FOR CONSUMPTION OF TANTALUM ORES AND CONCENTRATES, BY COUNTRY[1]

	2003		2004	
Country	Quantity, gross weight (metric tons)	Value (thousands)	Quantity, gross weight (metric tons)	Value (thousands)
Australia	1,330	$55,700	1,170	$52,100
Austria[2]	(3)	4	--	--
Canada	250	4,420	277	4,570
China	(3)	17	(3)	4
Ethiopia	--	--	30	1,240
Japan	--	--	(3)	30
Russia	(3)	5	--	--
United Kingdom	--	--	1	30
Total	1,580	60,100	1,480	57,900

-- Zero.
[1]Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Presumably country of transshipment rather than original source.
[3]Less than ½ unit.

Sources: U.S. Census Bureau and U.S. Geological Survey.

TABLE 8
PRINCIPAL WORLD COLUMBIUM AND TANTALUM RAW MATERIAL PRODUCERS

Country	Company and/or mine	Material type
Mining of columbium- and tantalum-bearing ores:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Columbium-tantalum.
Do.	Sons of Gwalia Ltd. (Wodgina)	Tantalum.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (Araxa)	Columbium.
Do.	Cia. de Estanho Minas Brasil[1]	Columbium-tantalum.
Do.	Paranapanema S.A. Mineracao Industria e Construcao (Pitinga)	Do.
Do.	Mineracao Catalao de Goias S.A.	Columbium.
Canada	Cambior Inc. and Mazarin Inc. (Niobec)	Do.
Do.	Tantalum Mining Corp. of Canada Ltd.[2]	Tantalum.
China	Government-owned	Columbium-tantalum.
Production of columbium- and tantalum-bearing tin slags:		
Australia	Sons of Gwalia Ltd. (Greenbushes)	Do.
Brazil	Cia. Industrial Fluminense[1]	Do.
Do.	Mamoré Mineracao e Metalurgia[3]	Do.
Thailand	Thailand Smelting and Refining Co. Ltd.	Do.
Production capacity for columbium- and tantalum-bearing synthetic concentrates, Germany, western states	H.C. Starck GmbH & Co. KG	Do.

[1]A wholly owned subsidiary of Metallurg Inc., New York, NY.
[2]A wholly owned subsidiary of Cabot Corporation.
[3]A subsidiary of Paranapanema S.A. Mineracao Indústria e Construcao.

TABLE 9
PRINCIPAL WORLD PRODUCERS OF COLUMBIUM AND TANTALUM PRODUCTS

Country	Company	Products[1]
Austria	Treibacher Industrie AG	Nb and Ta oxide/carbide, FeNb, NiNb.
Brazil	Cia. Brasileira de Metalurgia e Mineracao (CBMM)	Nb oxide/metal, FeNb, NiNb.
Do.	Cia. Industrial Fluminense[2]	Nb and Ta oxide.
Do.	Mineracao Catalao de Goias S.A. (Catalao)	FeNb.
Canada	Cambior Inc. and Mazarin Inc. (Niobec)	Do.
Estonia	Silmet	Nb oxide/metal.
Germany, western states	Gesellschaft fur Elektrometallurgie mbH (GFE)[2]	FeNb and NiNb.
Do.	H.C. Starck GmbH & Co. KG	Nb and Ta oxide/metal/carbide, K-salt, FeNb, NiNb, Ta capacitor powder.
Japan	Mitsui Mining & Smelting Co.	Nb and Ta oxide/metal/carbide.
Do.	Cabot Supermetals[3]	Ta capacitor powder.
Do.	H.C. Starck-V Tech Ltd.[4]	Do.
Kazakhstan	Ulba Metallurgical	Ta oxide/metal.
Do.	Irtysh Chemical & Metallurgical Works	Nb oxide/metal.
Russia	Solikamsk Magnesium Works	Nb and Ta oxide.
Thailand	H.C. Starck (Thailand) Co. Ltd.[4]	K-salt and Ta metal.
United States	Cabot Supermetals[3]	Nb and Ta oxide/metal, K-salt, Ta capacitor powder.
Do.	H.C. Starck Inc.[5]	Nb and Ta metal and Ta capacitor powder.
Do.	Kennametal Inc.	Nb and Ta carbide.
Do.	Reading Alloys Inc.	FeNb and NiNb.
Do.	Wah Chang[6]	Nb metal and FeNb.

[1]Nb, columbium; Ta, tantalum; FeNb, ferrocolumbium; NiNb, nickel columbium; K-salt, potassium fluotantalate; oxide, pentoxide.
[2]A wholly owned subsidiary of Metallurg Inc., New York, NY.
[3]A wholly owned subsidiary of Cabot Corporation.
[4]A subsidiary of H.C. Starck GmbH & Co. KG.
[5]Jointly owned by Bayer Corp. and H.C. Starck GmbH & Co. KG.
[6]A subsidiary of Allegheny Technologies Inc.

TABLE 10

COLUMBIUM AND TANTALUM: ESTIMATED WORLD PRODUCTION OF MINERAL CONCENTRATES, BY COUNTRY[1, 2]

(Metric tons)

	Gross weight[3]					Nb content[4]					Ta content[4]				
Country[5]	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004	2000	2001	2002	2003	2004
Australia, columbite-tantalite	1,600	2,220	3,100	2,500	2,000	160	230	290	230	200	485	660	940	765	730
Brazil:															
Pyrochlore	51,900	65,000	68,800	69,000	56,100	21,800	27,300	28,900	29,000	29,900	--	--	--	--	--
Tantalite	680	750	680	715	720	NA	NA	NA	NA	NA	190	210	190	200	250
Burundi	31 [6]	123 [6]	72 [6]	24 [r, 6]	25	NA	NA	NA	NA	NA	8	32	15	6 [r]	6
Canada:															
Pyrochlore	5,070	7,070	7,410	7,270	7,300 [6]	2,280	3,180	3,330	3,270	3,450 [6]	--	--	--	--	--
Tantalite	228	308	232	220	220 [6]	11	15	12	11	10 [6]	57	77	58	55	69 [6]
Congo (Kinshasa), columbite-tantalite	450	200	100	50	200	110	50	25	13	52	130	60	30	15	60
Ethiopia, tantalite	65 [6]	47 [6]	55 [r, 6]	55 [r]	55	7	5	6	6	6	39 [r]	28	35	35	35
Mozambique	25 [6]	27 [6]	47 [6]	189 [6]	712 [6]	5	5	8	34	130	10	11	19	75	280
Namibia	2	5	9	18	18	1	(7)	(7)	1	1	1	3	6	11	11
Nigeria, columbite-tantalite	469	610	156 [r, 6]	383 [r, 4]	400	200	250	65 [r]	160 [r]	170	23	30	8 [r]	21 [r]	21
Rwanda	561 [6]	241 [6]	96 [6]	128 [r, 6]	200	176	76	30	40 [r]	63	124	53	20	26 [r]	40
Uganda	3 [6]	11 [6]	6 [6]	16 [r, 6]	17	1	5	3	8 [r]	8	1	3	2	4 [r]	5
Zimbabwe	NA	30	481 [r]	231 [r]	14	NA	NA	NA	NA	NA	NA	9	144	69 [r]	4
Total	61,100	76,600	81,200 [r]	80,800 [r]	68,000	24,800	31,100	32,700 [r]	32,800	34,000	1,070	1,180	1,470 [r]	1,280 [r]	1,510

[r]Revised. NA Not available. -- Zero.

[1]World totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Excludes production of columbium and tantalum contained in tin ores and slags. Table includes data available through July 9, 2005.

[3]Data on gross weight generally have been presented as reported in official sources of the respective countries, divided into concentrates of columbite, tantalite, and pyrochlore where information is available to do so, and reported in groups, such as columbite and tantalite, where it is not.

[4]Unless otherwise specified, data presented for metal content are estimates based on, in most part, reported gross weight and/or pentoxide content.

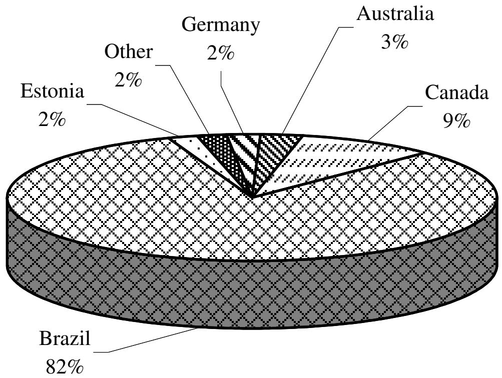
[5]In addition to the countries listed, Bolivia, China, French Guiana, Kazakhstan, and Russia also produce, or are believed to produce, columbium and tantalum mineral concentrates, but available information is inadequate to make reliable estimates of output levels.

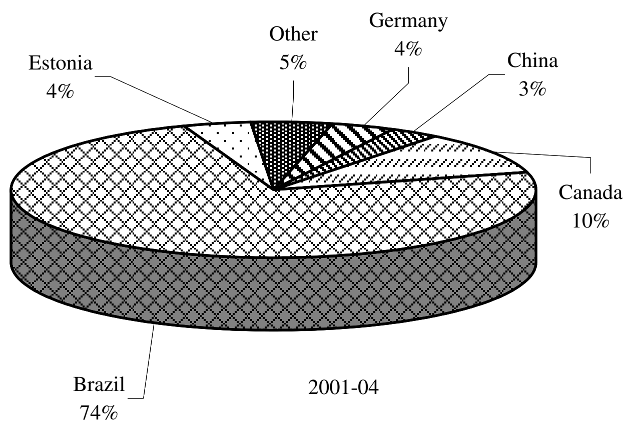
[6]Reported figure.

[7]Less than ½ unit.

FIGURE 1
MAJOR SOURCES OF U.S. COLUMBIUM IMPORTS

(Nb content)[e]

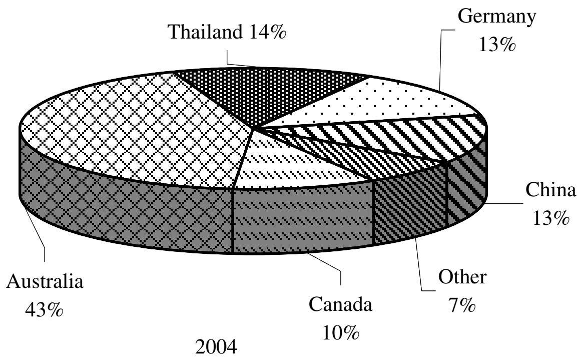




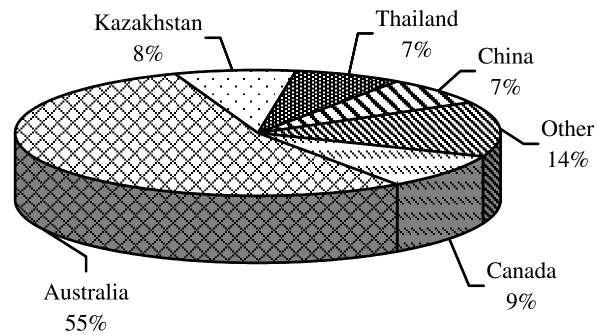
[e]Estimated.

FIGURE 2
MAJOR SOURCES OF U.S. TANTALUM IMPORTS

(Ta content)[e]



2004



2001-04

[e]Estimated.